



Third United Nations
International Conference
on the Peaceful Uses
of Atomic Energy

A/CONF.28/A/643
GERMANY, FEDERAL
REPUBLIC OF
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

Analytical Treatment of Neutron Thermalization in
Two Medium Wigner-Seitz Cells of Cylindrical Symmetry

by

H. Küsters
Kernforschungszentrum Karlsruhe

An analytical method is presented for solving the thermalization problem in space and energy for a cylindrical Wigner-Seitz cell, containing an infinitely long fuel rod surrounded by a moderator, which is treated as a monatomic gas. The energy loss of scattered neutrons in the fuel is neglected.

The Boltzmann equation is solved in both media by expanding the neutron distribution and the transfer scattering cross section in spherical harmonics. A system of coupled integro-differential equations results for the energy and space dependent expansion coefficients. This system first is solved for epithermal neutron energies ($E \gtrsim 16$ kT). In this region one can describe the energetical behaviour of the spectrum by a power series in $1/\sqrt{E}$ if one considers $1/\sqrt{E}$ -absorption only. In this region one cannot deal with the slowing down kernel for zero moderator temperature. Therefore all scattering integrals have been evaluated analytically with the asymptotic representation of the correct kernel.

This procedure leads to a system of inhomogeneous differential equations, which can be solved by the modified Besselfunctions of the second kind. The free constants in the fuel and moderator solutions are determined by the cell boundary conditions.

The epithermal solution is extrapolated to zero energies by multiplying with a "damping" function which vanishes with a sufficiently high power for $\xi \rightarrow 0$. Then the difference between the true spectrum and this artificial function is expanded in a system of orthonormal functions with an exponential asymptotic behaviour. The result is an inhomogeneous equation for this difference spectrum. If one deals with the unsymmetrized scattering kernel, the basis functions have to obey a certain condition, which guarantees the detailed balance of the representation of the kernel in this system. On the other hand the adjoint functions also have to include an exponential factor, because otherwise the expansion coefficients of the inhomogeneity may become infinity.

The general calculation to get the difference spectrum is straight forward. The homogeneous solution of the inhomogeneous equations in both the moderator and fuel media lead to an eigenvalue problem.

This method was first applied to the infinite medium case to look for convergence questions and consistency. As a test the integral neutron balance was calculated. The result is much better than one percent with four basis functions and an asymptotic expansion up to $1/\xi^4$. The cell calculations, done in a consistent P_1 -approximation, reproduce also the balance better than one percent with an epithermic expansion up to $1/\xi^2$. The dependence of the spectra on the moderator mass is investigated, also the influence of anisotropic scattering. It is seen that the average fuel spectrum deviates appreciably from the fuel boundary spectrum.

The mathematical formulation is carried on to P_3 -approximation, but numerical calculations have been done only in P_1 -approximation so far.



Third United Nations
International Conference
on the Peaceful Uses
of Atomic Energy

A/CONF.28/A/644
GERMANY, FEDERAL
REPUBLIC OF
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

Static and Dynamic Measurements on the Doppler Effect in an
Experimental Fast Reactor

by

W. Häfele^{*}, K. Ott^{*}, L. Caldarola^{**}, W. Schikarski^{*}, K. Cohen^{***},
B. Wolfe^{***}, P. Greebler^{***}

On the basis of present knowledge, it appears that the Doppler coefficient will be the only reliable prompt negative feedback mechanism present in fast power reactors. Design of fast power reactors will, therefore, be dependent upon and strongly influenced by a detailed understanding of the behaviour of the Doppler effect under various conditions, in particular operating and accident conditions.

There are principally two different tools to determine the Doppler effect in fast reactors: a fast neutron critical facility and an experimental fast reactor. In the present paper the complementary potentialities of these two tools are outlined and an experimental programme for the detailed examination of the Doppler effect in an experimental fast reactor is discussed. Such a programme requires the use of an experimental fast

^{*} Kernforschungszentrum Karlsruhe; the Karlsruhe Fast Breeder Project is a common enterprise as an association of Gesellschaft für Kernforschung and Euratom.

^{**} Euratom, delegated to the Karlsruhe Fast Reactor Project.

^{***} General Electric, Atomic Power Equipment Department.

reactor capable of safely undergoing both super-prompt critical and sub-prompt critical excursions. The Southwest Experimental Fast Oxide Reactor (SEFOR) has been designed specifically with this programme in mind. The requirements on the reactor and its design are briefly described. The various tests are discussed in detail. Special attention is given to the physical parameters involved in the evaluation of the Doppler effect and to the precision expected of the final results.

(1) Static Tests

In the static power tests, the fuel temperature is raised while keeping other temperatures relatively constant. The results will depend on the heat conductivity of the fuel.

(2) Oscillator Tests

Oscillator tests determine the transfer function of the reactor at various power levels. Both, the heat conductivity and the heat capacity influence strongly the results.

(3) Sub-Prompt Critical Step Tests

The results of these tests depend on the heat capacity and they are given in terms of delayed neutrons.

(4) Mild Super-Prompt Critical Ramp Excursions

Again the heat capacity of the fuel is of strong influence. The delayed neutrons are still of strong influence and the evaluation of the results has to take that into account.

(5) Strong Super-Prompt Critical Ramp Excursions

For the evaluation of the Doppler effect one only has to know the heat capacity of the fuel and the neutron life time of the reactor. It is expected to do these measurements with two SEFOR cores of different composition and it comes out that the various tests complement each other by providing data which have different dependence on the various properties of the fuel and the kinetics of the reactor.



**Third United Nations
International Conference
on the Peaceful Uses
of Atomic Energy**

A/CONF.28/A/645
GERMANY, FEDERAL
REPUBLIC OF
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

Theoretical and Experimental Investigations of
Slightly Enriched Zirconium-Hydride Moderated Lattices
by

K. Einfeld, G. Memmert

Interatom, Internationale Atomreaktorbau GmbH

In connection with the development of a heterogeneous zirconium-hydride moderated reactor, several critical and sub-critical measurements on lattices have been performed. These tests were performed in a fixed aluminium lattice by varying the arrangement of rods containing UO_2 or zirconium-hydride with equivalent diameters.

The time-dependent neutron flux behaviour after a neutron pulse was measured. The higher harmonic effects were eliminated through a numerical evaluation method which permitted the determination of the characteristic decay constants, as eigenvalues can also be directly calculated for a given system through theoretical methods which have been developed and employed for this purpose. The reliability of these methods can be illustrated with an example of a $\text{UO}_2\text{-H}_2\text{O}$ experimental core with a large reflector.

Measurements were performed on various zirconium-hydride lattices up to temperatures of 450°C in order to determine temperature dependence of the reactivity. This dependence is of special interest in the case of zirconium-hydride moderation. In this connection several theoretical expressions for the scattering kernel and for the heterogeneous spectrum methods were investigated in order to theoretically describe the experimental results as well as possible.

The critical experiments were performed on a split-table assembly of the Argonne "ZPR" type and were limited a maximum temperature of 200°C . The results of the sub-critical measurements were in essence verified by the critical assembly. In addition measurements with a pile-oscillator, threshold detectors and resonance detectors were made to obtain a very detailed determination of the cell-parameters. These measurements will, in turn, make possible the determination of the temperature dependancy of heterogeneous zirconium-hydride lattices.